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Infant feeding: the effects of scheduled vs. on-demand feeding on mothers' wellbeing and children's cognitive development

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Background: Many popular childcare books recommend feeding babies to a schedule, but no large-scale study has ever examined the effects of schedule-feeding. Here, we examine the relationship between feeding infants to a schedule and two sets of outcomes: mothers' wellbeing, and children's longer-term cognitive and academic development. **Methods:** We used a sample of 10 419 children from the Avon Longitudinal Study of Parents and Children, a cohort study of children born in the 1990s in Bristol, UK. Outcomes were compared by whether babies were fed to a schedule at 4 weeks. Maternal wellbeing indicators include measures of sleep sufficiency, maternal confidence and depression, collected when babies were between 8 weeks and 33 months. Children's outcomes were measured by standardized tests at ages 5, 7, 11 and 14, and by IQ tests at age 8. **Results:** Mothers who fed to a schedule scored more favourably on all wellbeing measures except depression. However, schedule-fed babies went on to do less well academically than their demand-fed counterparts. After controlling for a wide range of confounders, schedule-fed babies performed around 17% of a standard deviation below demand-fed babies in standardized tests at all ages, and 4 points lower in IQ tests at age 8 years. **Conclusions:** Feeding infants to a schedule is associated with higher levels of maternal wellbeing, but with poorer cognitive and academic outcomes for children.

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Introduction

Many of the childcare books on sale today advocate that babies should feed and sleep according to a schedule, and provide plans whereby parents may bring this about.^{1–4} Among these are a number of extremely popular titles: in 2006, three books by a single author accounted for 25% of all sales of childcare books in the UK.⁵ Authors of these books claim that schedules lead to happier babies, lower levels of stress and fatigue for parents, and an altogether easier experience of parenting; some also make indirect assertions relating to children's cognitive development.³ However, no research exists investigating the validity of these claims. We believe the current study is the first to do this: we used a large-scale child development survey to examine the relationship between schedule-feeding and maternal wellbeing, and the relationship between schedule-feeding and children's later cognitive development.

The few studies which have investigated feeding schedules find that demand feeding produces better outcomes, in terms of pre-term babies' growth and health^{6,7}; breastfeeding duration and exclusivity^{8,9}; and infants' psychological adjustment.¹⁰ However, these are considered short-term outcomes and cannot be used to draw inferences about longer-term effects. Conversely, studies which do consider longer-term outcomes in relation to infant feeding are

concerned with the effects of *what*, rather than *when*, babies are fed. Most of these studies^{11–15} report that breastfeeding is related to better cognitive outcomes; none report any findings related to feeding schedules.

Methods

Data

This study is based on the Avon Longitudinal Study of Parents and Children (ALSPAC, also known as Children of the 90s), a cohort survey of children born in the early 1990s in the Bristol area of the UK.^{16,17} A total of 14 541 mothers enrolled for the study during pregnancy; families were re-interviewed at intervals before and after the child's birth; and school attainment test data were obtained from local authorities.

Schedule-feeding

The variable of interest in this study is whether children were fed according to a schedule. When babies were 4 weeks old, mothers were asked: 'Is your baby fed (either by breast or bottle) on a regular

schedule (e.g. every 4 hours)? Mothers were asked to reply 'yes, always' (7.2%); 'yes, try to' (23.4%) or 'no, fed on demand' (69.4%).

Maternal wellbeing

This was assessed by questions asked when babies were aged between 8 weeks and 33 months. Maternal sleep sufficiency was measured at 8 weeks and 8 months by the question 'Do you feel you are getting enough sleep?' At 8 weeks, mothers were also asked whether they were feeling 'exhausted'. Two compound scales were derived from questions asked when babies were 8 and 33 months old: a 'maternal confidence' scale based on six items designed to capture mothers' confidence in their maternal capabilities, and a 'maternal enjoyment' score, constructed from five items.¹⁸

We also analysed questions at 8 weeks about whether mothers were feeling weepy, tearful and irritable; two questions relating to maternal confidence asked at 21 months; and the Edinburgh and Crown-Crisp post-natal depression scales at repeated intervals; these results are not reported, but they are discussed in the text.

Cognitive development and academic attainment

Cognitive development was measured using scores from IQ tests administered when children were aged 8 years. Academic attainment was measured via Standard Attainment Test (SATs) scores. These are school-based tests, which for the UK cohort in question were compulsory when most of the children were aged 7, 11 and 14, and which were optional, but widely administered, at age 5 years. At each age, we averaged each child's scores across three subjects: reading, writing and mathematics at 5 and 7 years and English, mathematics and science at 11 and 14 years. We controlled for age at testing in all regressions.

Exclusions and missing data

The core ALSPAC sample consists of 14 273 singleton births. Of these, we excluded 658 who did not survive, or who were born earlier than 28 weeks (possibly associated with atypical feeding patterns). Of the remaining children, over half had missing data for at least one of the control variables listed in table 1. These variables were collected from 11 questionnaires administered at 7 different points in time (see flow diagrams provided by ALSPAC^{18,19}), so a degree of partial non-response is expected; this arises predominantly from respondents failing to complete one or two whole questionnaires, rather than from item non-responses. Rather than dropping all such cases, we used the *mi* module in STATA to impute missing values using multiple imputation methods;^{20,21} in the Supplementary Appendix A1, we report results using different methods of dealing with missing data, which are for all practical purposes the same as those reported in the article.

Methods

For ease of interpretation, outcomes that may be considered as continuous variables (test scores, confidence and enjoyment scales and depression scores), have been standardized to have a mean of 0 and a standard deviation (SD) of 1. Multivariate analysis for these variables is by ordinary least squares (OLS); results are reported as percentages of a SD.

Discrete outcome variables have, where necessary, been recoded to reduce the number of categories to two. Multivariate analysis for these is via logistic regressions.

For both sets of outcomes, we present three specifications. Model A controls only for the child's sex (and in the case of test scores, age at testing). Model B controls for all the variables shown in table 1, except the two variables indicating breastfeeding durations. Model C also controls for the duration of exclusive breastfeeding, and for the

duration of non-exclusive breastfeeding following the cessation of exclusive breastfeeding.

The rationale behind comparing estimates from Models B and C is as follows. Research linking schedule-feeding to shorter breastfeeding durations²² suggests that one way in which schedule-feeding may affect outcomes is via its effect on breastfeeding. This is particularly likely when we consider test scores, since shorter breastfeeding durations have been linked to poorer cognitive and academic outcomes.^{13–15}

Model B controls for several aspects of breastfeeding measured prior to birth (parents' attitudes towards breastfeeding; their intentions regarding whether and how long to breastfeed, and whether the mother was breastfed herself); additionally, it controls for breastfeeding initiation. These variables are unlikely to have been affected by the mother's decision to feed to a schedule; thus, Model B estimates the total effect of schedule-feeding, including any effect which comes via breastfeeding duration.

Model C additionally controls for the duration of exclusive and non-exclusive breastfeeding (see 'Results' section for details of other specifications tested). Here, that part of the effect of schedule-feeding which comes via its effect on breastfeeding duration will be captured by the breastfeeding variables, and not by the schedule-feeding variables. Thus, Model C estimates the effect of scheduling, excluding the effect via breastfeeding duration. The difference between the estimated coefficients in Models B and C gives an indication of the size of the part of the relationship which is mediated via breastfeeding durations.

Finally, for the cognitive development outcomes, we present an additional set of estimates based on propensity score matching (PSM). This technique is used to address the fact that mothers who feed to a schedule have different characteristics to mothers who feed on demand, and this heterogeneity may not be adequately addressed by model-based analysis. PSM^{23,24} involves estimating the propensity of each mother in the sample to schedule-feed (using the same variables as in Model C), and using this propensity score to 'twin' each schedule-feeding mother with one or more counterparts from the demand-feeding group. The resulting 'treatment' and 'control' groups have almost identical distributions of all observable characteristics, and differ only in terms of the variable of interest (here, schedule-feeding). We implemented PSM using the *psmatch2* and *pstest* modules in STATA.

Results

Descriptive characteristics

Table 1 presents descriptive statistics for mother-and-baby pairs, by whether the mother reported feeding to a schedule at 4 weeks. There are sizeable differences between the groups. Babies fed to schedule are more likely to have been admitted to a SCBU unit (12.0% vs. 5.3% for demand-fed babies); they are smaller (3277 g vs. 3462 g), of lower gestational age, and their mothers are more likely to have smoked during pregnancy.

Breastfeeding rates are lower among schedule-fed babies, as is the mean duration of breastfeeding (7.5 weeks, vs. 21.6 weeks for demand-fed babies). This difference is partly attributable to the fact that schedule-fed babies are more likely to have been in SCBU. However, it is also related to the fact that fewer schedule-feeding mothers expressed an intention to breastfeed in ante-natal questionnaires.

Feeding to a schedule is also associated with less favourable socio-economic characteristics. Schedule-feeding mothers are younger; more likely to be single, more likely to be social tenants and less well educated. They are more likely to report poor health prior to and during pregnancy, and, when their children are older, they are more likely to smack and shout at them, and less likely to read to them.

Table 1 Characteristics of the study population according to whether fed to schedule

	Baby fed to schedule	Mother tried to feed to schedule	Baby fed on demand	All
Entire sample	7.1	23.0	69.8	
Pregnancy and birth related				
Male child ^a				
Baby was firstborn ^b	50.6	52.4	50.8	51.1
Admitted to Special Care Baby Unit ^c	26.2	30.4	32.5	31.5
Birthweight, g (mean) ^a	12.0	5.1	5.3	5.7
Gestation, weeks (mean) ^a	3277 (627)	3460 (497)	3462 (501)	3448 (523)
Delivered by c-section ^d	39.1 (2.4)	39.6 (1.6)	39.6 (1.7)	39.6 (1.7)
Mother: cigs/day, 8 weeks preg (mean) ^b	10.9	10.2	9.7	9.9
Breastfeeding	3.0 (5.9)	2.0 (4.9)	1.7 (4.8)	1.9 (4.8)
Mother's attitude to breastfeeding ^{a, g}	15.2 (3.4)	15.1 (3.3)	16.6 (3.3)	16.1 (3.4)
Father's attitude to breastfeeding ^{a, g}	14.9 (2.7)	15.0 (2.7)	15.9 (2.7)	15.6 (2.7)
Mother intended to breastfeed ^b	48.9	53.2	74.9	67.6
Mother was breastfed herself ^b	46.6	54.5	60.8	58.4
Mother initiated breastfeeding ^c	55.0	65.7	82.0	76.3
Breastfeeding duration (mean, weeks) ^h	7.5 (13.7)	8.3 (13.9)	21.6 (21.6)	17.5 (19.9)
Exclusive breastfeeding (mean, weeks) ^h	2.4 (4.0)	2.6 (4.0)	5.1 (5.3)	4.4 (5.1)
Parenting				
Mother reads to child almost daily ^e	64.6	66.1	72.7	70.7
Father reads to child almost daily ^e	30.5	29.6	33.3	32.3
Mother smacks child weekly or more ^f	37.6	39.0	33.0	34.6
Mother shouts at child daily ^f	42.8	43.1	38.9	40.1
Maternal health				
Poor health prior to pregnancy ^b	9.7	7.9	6.6	7.2
Poor health during pregnancy ^b	26.9	25.2	23.3	24.0
Depression (Edinburgh score, mean) ^b	7.4 (5.4)	6.9 (4.6)	6.6 (4.7)	6.7 (4.7)
Socio-demographic				
Maternal age, years (mean) ^b	26.4 (4.7)	27.6 (4.6)	29.0 (4.6)	28.6 (4.7)
No father figure ^b	4.2	2.3	1.7	2.0
Mother was in care as a child ^b	3.4	2.1	2.4	2.4
Mother—degree ^b	5.6	7.6	17.5	14.5
Mother—'A' levels ^b	15.4	19.8	27.5	24.9
Mother—'O' levels ^b	37.0	42.5	35.6	37.3
Mother—less than 'O' level ^b	42.0	30.1	19.3	23.3
Father—degree ^b	8.4	12.5	24.6	20.8
Owner occupiers ^b	65.3	77.3	80.2	78.5
Private rented ^b	7.5	6.7	6.2	6.4
Social housing (+other) ^b	27.2	16.1	13.6	15.1
Index of neighbourhood quality (mean) ^{b, i}	8.0 (2.4)	8.2 (2.1)	8.2 (2.2)	8.2 (2.2)

All figures are percentages of the scheduling subgroup in question, or of the whole sample, except where means are reported—in which case, standard deviations are also given in parentheses.

All variables differ significantly at the 5% level between scheduling subgroups, except: the baby's sex, delivery by c-section, whether the mother was in care as a child, and housing in the private rented sector.

Regressions additionally include quadratic terms in birthweight and gestation

Time of measurement,

a: around birth

b: ante-natally

c: 4 weeks

d: 8 weeks

e: 18 months

f: 42 months

g: Synthesized from a battery of questions; ALSPAC variables c617 (mother) and pb576 (father); range 3–23

i: Interviewer's assessment (ALSPAC variable 636) ranges from 1 to 12

h: Derived from questions on infant feeding asked at intervals after birth

Mothers who tried to feed to a schedule fall in between schedule- and demand-feeding mothers on most measures. However, on several important measures (breastfeeding attitudes, intentions, and durations, parental education, and parenting behaviours) mothers who tried to feed to a schedule are much more similar to schedule-feeding mothers than to demand-feeding mothers.

Schedule-feeding and maternal wellbeing

Table 2 reports the results of regressions estimating the relationships between schedule-feeding and maternal wellbeing. On all these measures, schedule-feeding mothers reported higher levels of wellbeing. In Model C (full controls), schedule-feeding mothers

were 1.55 (1.31–1.84) times more likely than demand-feeding mothers to report getting enough sleep at 8 weeks; this difference persists at 8 months.

Schedule-feeding mothers are less likely than demand-feeding mothers to report feeling exhausted at 8 weeks; and their more positive experience is repeated in the maternal confidence and enjoyment scales; in the adjusted models, schedule-feeding mothers report higher scores than demand-feeding mothers (around 17% of a standard deviation), at 8 and 33 months. Additionally, very similar findings apply to four other measures which we do not report.

However, our findings in relation to the Edinburgh and Crown-Crisp post-natal depression scores, which in ALSPAC are

Table 2 Schedule-feeding and maternal wellbeing

	Model A	Model B	Model C
Mother getting enough sleep, 8 weeks (OR)	(n = 10 984)	(n = 10 300)	(n = 10 300)
Tried schedule	1.22 (1.11–1.33)***	1.11 (1.00–1.23)*	1.07 (0.96–1.19)
Fed to a schedule	1.81 (1.56–2.10)***	1.60 (1.36–1.90)***	1.55 (1.31–1.84)***
Mother getting enough sleep, 8 months (OR)	(n = 10 417)	(n = 9824)	(n = 9824)
Tried schedule	1.36 (1.23–1.50)***	1.27 (1.14–1.40)***	1.15 (1.04–1.28)*
Fed to a schedule	1.99 (1.68–2.35)***	1.76 (1.46–2.11)***	1.62 (1.34–1.95)***
8 weeks: sometimes exhausted (OR)	(n = 10 990)	(n = 10 314)	(n = 10 314)
Tried schedule	0.94 (0.81–1.08)	1.02 (0.87–1.20)	1.01 (0.86–1.19)
Fed to a schedule	0.42 (0.35–0.51)***	0.53 (0.43–0.65)***	0.52 (0.42–0.64)***
Maternal confidence scale, 8 months (OLS)	(n = 10 386)	(n = 9802)	(n = 9802)
Tried schedule	6.4 (1.8–11.0)***	2.6 (–2.1 to 7.2)	0.6 (–4.1 to 5.4)
Fed to a schedule	27.4 (19.8–35.0)***	20.1 (12.4–27.8)***	18.4 (10.7–26.1)***
Maternal confidence scale, 33 months (OLS)	(n = 8933)	(n = 8487)	(n = 8487)
Tried schedule	5.6 (0.5–10.6)*	1.8 (–3.3 to 6.8)	1.1 (–4.0 to 6.3)
Fed to a schedule	21.0 (12.6–29.2)***	17.1 (8.6–25.6)***	16.6 (8.0–25.1)***
Maternal enjoyment scale, 8 months (OLS)	(n = 10 328)	(n = 9740)	(n = 9740)
Tried schedule	–0.6 (–5.3 to 4.0)	0.5 (–5.2 to 4.3)	0.0 (–4.9 to 4.9)
Fed to a schedule	19.2 (11.5–26.8)***	16.1 (8.2–24.1)***	16.6 (8.5–23.2)***
Maternal enjoyment scale, 33 months (OLS)	(n = 8938)	(n = 8488)	(n = 8488)
Tried schedule	–1.8 (–6.7 to 3.3)	0.4 (–4.8 to 5.6)	0.7 (–4.6 to 6.0)
Fed to a schedule	15.4 (7.1–23.7)***	16.5 (7.7–25.1)***	16.7 (8.0–25.4)***

Coefficients in the upper part of the table (marked OR) are odds ratios from Logit regressions, relative to the reference category (demand-fed); those marked (OLS) in the lower part of the table represent the percentage of a standard deviation in the (continuous) outcome associated with each feeding mode. 95% confidence intervals are given in parentheses. *P*-values are indicated by asterisks, with **P* < 0.05, ***P* < 0.01, ****P* < 0.001.

measured at 8 weeks, and at 8, 21 and 33 months, are rather different. On these scales—whether we treat them as continuous or dichotomous indicators—we observed no difference between schedule- and demand-feeding mothers; thus, the increased wellbeing enjoyed by schedule-feeding mothers does not translate into a lower risk of depression for these women.

Schedule-feeding and cognitive outcomes

Table 3 presents the relationships between schedule-feeding and test results. The raw coefficients (Model A) indicate a gap between demand-fed children and those whose mothers tried to feed them to a schedule but were not successful. However, when controls are added (Models B and C), these differences disappear almost entirely.

In contrast, the differences between demand-fed children and those who were actually fed to a schedule are much larger, and do not disappear in the adjusted models. Model B, which estimates the total effect of schedule feeding, shows that schedule-fed babies do consistently worse than their demand-fed counterparts, by around 18.4% of a standard deviation in SATs tests, and by 4.5 IQ points.

Model C, as expected, produces slightly lower estimates, averaging around 16.7% of a standard deviation. This suggests that, of the 0.184 SD gap between demand- and schedule-fed children, around 0.017 SD is attributable to the effect of lower breastfeeding durations among schedule-feeding mothers. All differences in test scores between schedule- and demand-fed children are very highly significant (*P* < 0.001).

The final column in table 3 presents estimates from PSM analysis, which may be better than regression-based approaches at dealing with heterogeneity between schedule- and demand-feeding mothers. PSM produces estimates which are a little larger than, but essentially very close to, the OLS estimates.

Figure 1 demonstrates the relative importance of the explanatory variables used in regressions. Starting with a completely unadjusted model, we add groups of controls in sequence, and graph estimated coefficients for schedule-fed relative to demand-fed children. The variables which make by far the largest difference to our estimates relate to parental education: all ten sets of variables subsequently added to the model do little to change our estimated results. We return later to the importance of this fact.

Robustness checks

As well as the reported analyses, we performed a series of additional robustness checks. First, we investigated the issue of confounding by indication which may arise if babies born in poorer condition are more likely to be fed to a schedule (e.g. because of routines established in special care units, or because they are less likely to display obvious signs of hunger). A simple test involved restricting the analysis to babies born between 38 and 41 weeks, and weighing between 2820 g and 4250 g at birth; we also tested several more complex specifications, refining the quadratic terms in gestation and birthweight used in the original specifications, and adding interaction terms between schedule-feeding and birthweight and gestation. These did not change our findings.

We also investigated the role of breastfeeding in more detail, testing several functional forms for the breastfeeding durations in Model C. We also tested for interactions between schedule-feeding and breastfeeding, first stratifying by breastfeeding status, and then by including interaction terms between schedule-feeding and breastfeeding (specified both dichotomously and continuously). Again, the effect of schedule-feeding remained statistically significant.

Discussion

Our results suggest that feeding infants to a schedule is associated with better maternal wellbeing (in the form of more sleep, and higher scores on parenting enjoyment and confidence scales) until at least 33 months of age. However, there appears to be a trade-off: children who were fed to a schedule go on to do less well in attainment and IQ tests, at all ages from 5 to 14 years. After controlling for a wide range of background variables, we estimate that schedule-fed children do worse than their demand-fed counterparts by 18.4% of a standard deviation; of this, around 1.7% is attributable to different breastfeeding durations between schedule- and demand-feeding mothers.

It is important to stress the possibility that these relationships, while statistically very highly significant (*P* < 0.001) and robust to a wide range of controls and specification tests, may not be causal.

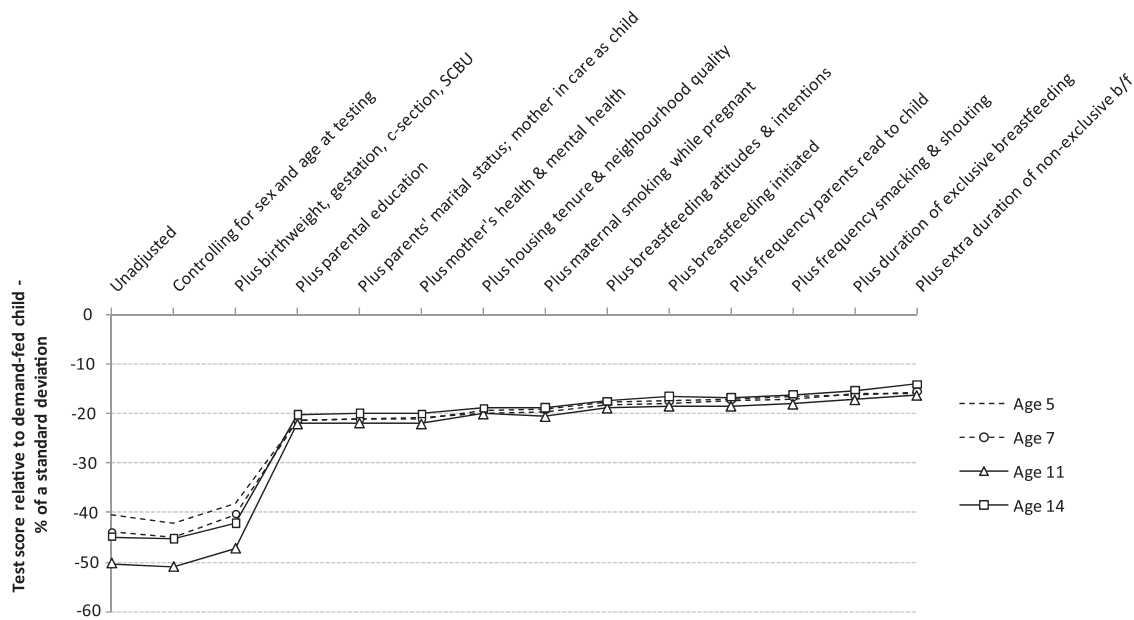
It may be that the findings on maternal wellbeing arise from reverse causality—perhaps mothers who were getting more sleep or felt more confident were more likely to initiate and succeed in

Table 3 Schedule-feeding and child cognitive outcomes

	Model A (OLS)	Model B (OLS)	Model C (OLS)	Model C (PSM)
Age 5 SATs tests	(n = 7972)	(n = 7331)	(n = 7331)	(n = 1687 tried, 475 scheduled)
Tried schedule	-7.8 (-12.8 to -3.1)**	0.1 (-4.6 to 4.9)	1.7 (-3.1 to 6.5)	3.7 (-3.0 to 10.3)
Schedule	-44.1 (-51.6 to -36.6)***	-20.3 (-27.9 to -12.7)***	-18.9 (-26.5 to -11.3)***	-16.8 (-28.0 to -5.6)***
Age 7 SATs tests	(n = 8466)	(n = 8687)	(n = 8687)	(n = 1978 tried, 583 scheduled)
Tried schedule	-7.9 (-12.4 to -3.3)**	3.7 (-0.7 to 8.2)	5.0 (0.5-9.5)*	4.6 (-1.6 to 10.7)
Schedule	-42.9 (-49.9 to -35.9)***	-15.5 (-22.5 to -8.5)***	-14.5 (-21.5 to -7.4)***	-18.0 (-28.3 to -7.8)***
Age 11 SATs tests	(n = 10 239)	(n = 9432)	(n = 9432)	(n = 2103 tried, 580 scheduled)
Tried schedule	-20.0 (-24.5 to -15.5)***	-3.1 (-7.4 to 1.2)	-0.3 (-4.7 to 4.0)	2.4 (-3.5 to 8.4)
Schedule	-52.7 (-59.9 to -45.5)***	-20.0 (-27.0 to -13.0)***	-17.7 (-24.6 to -10.6)***	-21.2 (-31.6 to -10.9)***
Age 14 SATs tests	(n = 9013)	(n = 8313)	(n = 8313)	(n = 1884, tried, 529 scheduled)
Tried schedule	-16.2 (-21.1 to -11.4)***	-1.2 (-5.8 to 3.4)	1.5 (-3.2 to 6.2)	1.5 (-4.7 to 7.7)
Schedule	-47.5 (-55.0 to -39.9)***	-17.7 (-25.1 to -10.2)***	-15.5 (-23.0 to -8.1)***	-17.0 (-27.9 to -6.1)***
Age 8 IQ scores	(n = 6515)	(n = 6205)	(n = 6205)	(n = 1278 tried, 298 scheduled)
Tried schedule	-3.4 (-4.4 to -2.5)***	-0.7 (-1.6 to 0.3)	-0.4 (-1.4 to 0.5)	-0.2 (-1.4 to 1.0)
Schedule	-8.9 (-10.6 to -7.1)***	-4.5 (-6.2 to -2.8)***	-4.3 (-5.9 to -2.6)***	-4.1 (-6.3 to -1.9)***

Estimates for models A, B and C are from OLS regressions, with coefficients reflecting differences between the 'tried schedule' and 'schedule-fed' groups, and the omitted category (demand-fed children). Coefficients at ages 5, 7, 11 and 14 years are in terms of percent-ages of a standard deviation; coefficients at age 8 years reflect IQ points. Model A controls only for child's sex and age at testing. Model B controls, additionally, for all variables in table 1 except breastfeeding durations. Model C controls, additionally, for duration of exclusive breastfeeding and for additional duration of non-exclusive breastfeeding following the cessation of exclusive breastfeeding. 95% confidence intervals are given in parentheses. *P*-values are indicated by asterisks, with **P* < 0.05, ***P* < 0.01, ****P* < 0.001.

The PSM procedure was implemented twice for each outcome, first comparing children in the 'tried schedule' group with matched counterparts from the 'demand-fed' group, and secondly comparing children in the 'schedule' group with matched counterparts from the 'demand-fed' group. Sample sizes relate to the number of children in each of the two 'treatment' groups who could be satisfactorily matched with one or more demand-fed children. Each child in the 'tried schedule' group was matched with up to three near neighbours from the demand-fed group, and each child in the smaller 'schedule' group was matched with up to five near neighbours from the demand-fed group. We specified that the propensity to schedule-feed of treatment group members and their matched counterparts must differ by no more than a 'caliper' of 0.0005 to about 0.5% of the standard error of the propensity score. We experimented with different calipers and different numbers of matched neighbours, with no changes to the results.



Note: effects shown are expressed as percentages of a standard deviation

Figure 1 Estimated effects of schedule feeding on test scores, controlling for different sets of confounders

establishing a schedule. 'Pure' reverse causality is less likely to apply in respect of cognitive development, since this type of outcome is unlikely to be evident or observed at 4 weeks of age. However, in this case other problems may apply. Failing to control adequately for between-group differences in maternal characteristics or behaviour or other aspects of a child's background, would lead to residual confounding. We believe there are two reasons why, while residual

confounding may account for part of the observed relationships, it is unlikely to account for the relationships in their entirety. First, figure 1 shows that in order for residual confounding to be responsible for the entire relationship, we would need to have omitted a variable, or set of variables, over three times as important as parents' marital status, maternal health, mental health, housing tenure, neighbourhood quality, smoking, breastfeeding attitudes and

intentions, breastfeeding initiation and duration, reading to children, smacking and shouting, all put together. Thus, we cannot rule out residual confounding as an explanation for our findings, but we believe it would be wrong to jump to the conclusion that our findings must necessarily be due to confounding.

Another reason to believe that the relationship between schedule-feeding and cognitive outcomes may be at least partly causal lies in the fact that, as noted previously, mothers who tried to feed to a schedule have characteristics far more similar to those who actually fed to a schedule than to demand-feeding mothers. In contrast, the test scores of babies whose mothers tried to feed them to a schedule are much more similar to the scores of demand-fed babies than to those of schedule-fed babies. This is true even before controlling for confounders; after controlling for confounders, there is no difference at all between children who were demand-fed and children whose mothers tried to feed to a schedule, while children who were actually fed to a schedule do significantly worse than both these other groups. This suggests that it is *actually* having been fed to a schedule, rather than having the type of mother who *attempted* to feed to a schedule (successfully or not) which makes the difference.

What might be the mechanisms behind such causal relationships? We have already noted that part (but only part) of the difference between schedule- and demand-fed children arises via the effect of schedule-feeding on breastfeeding rates. A second route may be biological. Most studies of the effects of feeding frequency have focused on breastfed infants and are concerned with factors such as breastmilk composition^{25,26} and infant weight gain.²⁷ However, it is not inconceivable that the brain development of bottle-fed infants is also affected by the frequency with which they are fed.

A third route may be via the acquisition of personality traits in infants. It is possible that babies fed to a routine become relatively more passive participants in the world: feeding (arguably the most important event in their lives) is something which is done to them, rather than something which their own desires and actions play a part in bringing about. This may translate, in later life, into a less active degree of engagement with learning.

This study is the first to investigate the longer term effects of scheduled vs. on-demand feeding in infants. Given the plethora of parenting books which recommend feeding schedules for babies, this is clearly an area of huge potential relevance for policy.

Clearly, however, this study leaves many questions unanswered. It is based on a single question on infant feeding asked at 4 weeks, and cannot answer questions relating to the effects of scheduling at different ages in a child's life; or different types of routines (3-hourly, 4-hourly or routines which vary across the course of a day); or why some parents choose to feed to a schedule while others feed on demand. These questions cannot currently be answered by survey-based studies because ALSPAC is the only longitudinal study carrying any questions on feeding schedules. However, new surveys are being implemented in several countries, and we hope that our findings will provide an impetus for these to include questions on feeding schedules.

We also hope our work will provide a springboard for other types of research on this issue, since we have raised several questions which cannot easily be addressed by observational studies. In particular, randomized controlled trials could settle the issue of confounding decisively, whereas small-scale qualitative studies could provide insights into the reasons why mothers choose to feed in the way they do, and the relationship between (for example) maternal temperament, parenting style and feeding mode.

Ethical approval

Ethical approval for the study was obtained from the ALSPAC Law and Ethics committee and the Local Research Ethics Committees.

Data sharing

ALSPAC data are available, on application, from: Children of the 90s, Oakfield House, Oakfield Grove, Bristol, BS8 2BN

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Conflicts of interest: None declared.

Key points

- Mothers who feed their babies to a schedule at 4 weeks report higher levels of wellbeing, at all stages from 8 weeks postpartum to 33 months.
- However, babies who were fed to a schedule go on to perform less well academically than babies who were fed on demand. This difference is ~17% of a standard deviation.
- Schedule-fed babies also go on to do less well than demand-fed babies in IQ tests administered at age 8 years, by around 4 IQ points.
- This is the very first research on this issue, and there is a clear need for child development surveys to include questions on the timing of infant feeding, to enable further research to be carried out.

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Low vigorous physical activity at ages 15, 19 and 27: childhood socio-economic position modifies the tracking pattern

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Background: The present study examines (i) if the level of vigorous physical activity (VPA) at age 15 predicts low VPA at ages 19 and 27 and (ii) whether the observed prediction pattern differs by childhood socio-economic position (SEP). In this way, prediction analyses are applied to study tracking behaviour. **Methods:** Data are from The Danish Longitudinal Health Behaviour Study. The baseline survey was conducted in 1990 at age 15, the first follow-up in 1994 at age 19, and the second follow-up in 2002 at age 27, $n = 561$. The study population was a random sample of the Danish population selected from the National Civic Registration System, and data were collected by anonymous postal questionnaires. The indicator of childhood SEP was family occupational social class. Prediction analyses are conducted by stratified logistic regression analyses. **Results:** There was a significant and marked predictive power of low levels of VPA in mid adolescence (aged 15) for low VPA in late adolescence (age 19) [odds ratio (OR)=4.95 (2.83–8.66)], from late adolescence (age 19) into early adulthood (age 27) [OR=2.71 (1.61–4.55)] and also over the full study period from age 15 to age 27 [2.91 (1.72–4.94)]. Analyses stratified by SEP revealed that the predictive power of VPA at age 19 for low VPA at age 27 was only significant among participants from low SEP. **Conclusion:** These findings suggest that low VPA tracks through adolescence while tracking into adulthood only occurs among individuals with low childhood SEP.
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